

## METHOD FOR THE PREPARATION OF CONTROLLED RELEASE FORMULATIONS

### Field of the Invention

5       The present invention relates to a method of making controlled release compositions; and, specifically to a method of contacting an organic solution containing a bioactive agent and a polymer with an aqueous solution containing an organic ion through an emulsion process to create controlled release compositions. The present invention further provides methods of using controlled release  
10       compositions including a polymer, an organic ion and a bioactive agent.

### BACKGROUND OF THE INVENTION

          Currently there are numerous controlled release formulations on the market that contain various bioactive agents, such as GnRH analogs, human growth  
15       hormone, risperidone and somatostatin analogs of which octreotide acetate is an example. These controlled release compositions are typically formulated with biodegradable, biocompatible polymers. Such formulations are preferred by healthcare professionals and their patients because they reduce the need for multiple injections. Additionally, since one injection treats a patient for a prolonged period of  
20       time, health care organizations prefer them because they decrease the number of office visits per patient, which works to decrease health care costs.

          Unfortunately, there are many problems with the current production processes and formulations for controlled release compositions. Many current manufacturing processes are incapable of producing concentrated product exhibiting  
25       a high drug load, thus necessitating a large intramuscular injection volume (2 mL) that is quite uncomfortable for the patient when administered. Additionally, many methods require time consuming and complex procedures to solubilize bioactive agents prior to encapsulation; and manipulation of solubility for purposes of encapsulation can result in deleterious release profiles, as well as degradation of the  
30       bioactive agent itself. For example, the use of highly water soluble bioactive agents frequently results in an undesirable "burst" of bioactive agent upon contact with an aqueous solution, such as by administration to a patient or introduction to a physiological medium. Such a rapid rise in levels of bioactive agent can be

detrimental to a patient and may leave little bioactive agent for later release over the desired treatment time course.

Various methods of solving the solubility problem have been attempted but none have been particularly efficient or effective. One such attempt combined a  
5 bioactive agent with a surfactant molecule, comprising an anionic head and a hydrophobic tail, to solubilize the bioactive agent in an organic phase prior to encapsulation. Another method combined organic acids with the bioactive agent to produce a water insoluble addition salt prior to encapsulation. The use of an insoluble additional salt resulted in a lessening of the "burst" effect upon  
10 administration; however, this method required additional manufacturing procedures that made production of these compounds expensive and inefficient. Another method included encapsulation of the acetate salt of the bioactive agent that resulted in substantial amounts of chemically modified or degraded bioactive agent being released after placement in an aqueous physiological buffer. Chemical degradation  
15 was in the form of undesirable acylation of the bioactive agent.

Methods of producing controlled release compositions that are capable of producing a product with a high drug load, minimum burst effect upon administration and minimum degradation of the bioactive agent are greatly needed to realize the true benefits of these types of compositions as human or veterinary therapeutics.

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## SUMMARY OF THE INVENTION

In accordance with the purpose(s) of this invention, as embodied and broadly described herein, this invention, in one aspect, relates to methods of making and using controlled release compositions.

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In one embodiment, the method includes the steps of combining a bioactive agent and a polymer in an organic phase; combining an organic ion in an aqueous phase; and contacting the resulting organic and aqueous phases to produce a controlled release composition.

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In a certain embodiment, the method includes the steps of combining a bioactive agent and a polymer in an organic phase; combining an organic ion in an aqueous phase; and subjecting the resulting organic and aqueous phases to an emulsion process to produce a controlled release composition.

5 In a certain embodiment the method includes contacting an organic phase comprising a polymer and a bioactive agent with a water phase comprising an organic ion wherein an effective quantity of an organic ion leaves the aqueous phase and enters the organic phase.

10 In one embodiment, the organic phase comprises a solvent selected from the group consisting of, but not limited to, methylene chloride, ethyl acetate, benzyl alcohol, acetone, acetic acid and propylene carbonate.

15 In a particular embodiment, the organic phase further includes a cosolvent. The cosolvent may be selected from the group consisting of, but not limited to, dimethyl sulfoxide, dimethyl formamide, n-methylpyrrolidinone, PEG<sub>200</sub>, PEG<sub>400</sub>, methyl alcohol, ethyl alcohol, isopropyl alcohol and benzyl alcohol.

20 In another embodiment, the aqueous phase further includes an emulsifying agent. The emulsifying agent may be selected from the group consisting of, but not limited to, poly(vinyl alcohol), albumin, lecithin, vitamin E- D-alpha-tocopheryl polyethylene glycol (TPGS) and polysorbates. In a particular embodiment, the emulsifying agent may be present at a final concentration ranging from about 0.1 to 10% (w/w).

25 In a certain embodiment, the organic ion is at a final concentration ranging from about 0.1 to 1000 mM.

In a certain embodiment, the controlled release composition is selected from the group consisting of, but not limited to, microparticles and nanoparticles. In a particular embodiment, the microparticles and nanoparticles are biodegradable.

30 In another embodiment, the polymer may be selected from the group consisting of, but not limited to, poly(lactide)s, poly(glycolide)s, poly(lactide-co-glycolide)s, poly(lactic acid)s, poly(glycolic acid)s, poly(lactic acid-co-glycolic acid)s, polycaprolactone, polycarbonates, polyesteramides, polyanhydrides, poly(amino acids), polyorthoesters, polyacetyls, polycyanoacrylates, polyetheresters, 35 poly(dioxanone)s, poly(alkylene alkylate)s, copolymers of polyethylene glycol and

poly(lactide-co-glycolide), biodegradable polyurethanes, blends and copolymers thereof.

5 In another embodiment, the bioactive agent may be selected from the group consisting of, but not limited to, proteins, nucleic acids, peptides, small molecule pharmaceutical substances, immunogens, metabolic precursors capable of promoting growth and survival of cells and tissues, antineoplastic agents, hormones, antihistamines, cardiovascular agents, anti-ulcer agents, bronchodilators, vasodilators, central nervous system agents, narcotic antagonists and the like.

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In a certain embodiment, the emulsion process is selected from the group consisting of oil-in-water and water-oil-water.

15 In a particular embodiment, the methods of the present invention may be practiced with any known emulsion process.

In a particular embodiment the organic ion is selected from the group consisting of anionic and cationic materials. In a particular embodiment, the organic ion is selected from pamoate, trifluoromethyl-p-toluate, cholate, 2-naphthalene  
20 sulfonate, 2,3-naphthalene dicarboxylate, 1-hydroxy-2-naphthoate, 3-hydroxy-2-naphthoate, 2-naphthoate and salicylsalicylate.

In another embodiment, degradation includes acylation. In a particular embodiment the acylation reaction involves nucleophilic attack of an amino group of  
25 a bioactive agent directed to a carbonyl carbon of a polyester such as poly(d,l-lactide-co-glycolide). It is hypothesized that degradation of the bioactive agent is prevented or reduced in the present compositions by facilitated protonation of potential nucleophiles (e.g., amino groups), thus rendering the nucleophiles less apt to participate in acylation reactions with the PLGA polymer backbone or fragments  
30 thereof.

In another embodiment degradation includes lysis of the polymer. Excessive lysis may lead to rapid loss of polymer molecular weight and premature release of bioactive agent.

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In another embodiment, the molar stoichiometry of the bioactive agent relative to the organic ion ranges from about 0.5 to 2.0. In a particular embodiment the molar stoichiometry of the bioactive agent relative to the organic ion ranges from about 1.0 to 1.5.

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In another certain embodiment, the present invention provides a controlled release composition including a polymer and a bioactive agent in the form of a complex with an organic ion. Such a complex may be formed when an organic ion and a bioactive agent form a close physical association.

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In another embodiment the bioactive agent content may be increased relative to the bioactive agent content of compositions prepared by the method of the present invention in the absence of an organic ion.

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In another embodiment, the present invention includes a method of combining a bioactive agent with an organic phase; combining a polymer with the same organic phase; combining an organic ion with an aqueous phase; and contacting the organic phase and aqueous phase through the use of an emulsion process in order to produce an encapsulated form of the bioactive agent.

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Additional advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general

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description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

## DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

### Definitions

For the purposes of the present invention, the following terms shall have the following meanings:

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For the purposes of the present invention, the term "biodegradable" refers to polymers that dissolve or degrade *in vivo* within a period of time that is acceptable in

a particular therapeutic situation. Such dissolved or degraded product may include a smaller chemical species. Degradation can result, for example, by enzymatic, chemical and/or physical processes. Biodegradation takes typically less than five years and usually less than one year after exposure to a physiological pH and temperature, such as a pH ranging from 6 to 9 and a temperature ranging from 22C to 38C.

For the purposes of the present invention, the terms "organic phase" and "discontinuous phase" are interchangeable and refer to the solution of solvent, polymer and bioactive agent created in the methods of the present invention that will then be contacted with an aqueous phase through an emulsion process in order to create the controlled release compositions of the present invention.

For the purposes of the present invention, the term "degradation" refers to any unwanted modification to the bioactive agent, such as acylation, or to the polymer, such as lysis.

For the purposes of the present invention, the terms "aqueous phase" and "continuous phase" are interchangeable and refer to the solution of water and organic ion agent created in the methods of the present invention that will then be contacted with an organic phase through an emulsion process in order to create the controlled release compositions of the present invention.

For the purposes of the present invention, the term "combining" refers to any method of putting two or more materials together. Such methods include, but are not limited to, mixing, blending, commingling, concocting, homogenizing, incorporating, intermingling, fusing, joining, shuffling, stirring, coalescing, integrating, confounding, joining, uniting, and the like.

For the purposes of the present invention, ranges may be expressed herein as from "about" or "approximately" one particular value, and/or to "about" or "approximately" another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another embodiment. It will be further understood that the endpoints of each of the ranges

are significant both in relation to the other endpoint, and independently of the other endpoint.

For the purposes of the present invention, the term "bioactive agent" refers to any agent with biological activity either *in vivo* or *in vitro*, where biological activity may be detected as an observable change in overall health or at least one health marker (i.e., symptom) of an individual, as a change in a relevant surrogate biological marker or as a change in the chemical structure or conformation of a physiologically relevant molecule.

For the purposes of the present invention, the term "organic ion" refers to cationic and anionic materials. Organic ions may be present in their salt or acid forms. Exemplary organic ions include pantoate, naphthoate, cholate and the like.

For the purposes of the present invention, a "controlled release composition" shall refer to any formulation with a different release profile than native bioactive agent. Typically release profiles will include physiologically detectable concentrations of a bioactive agent over a period of at least one week, at least one month, at least 45 days, or for longer than 45 days.

Moreover, for the purposes of the present invention, the term "a" or "an" entity refers to one or more of that entity; for example, "a protein" or "an peptide" refers to one or more of those compounds or at least one compound. As such, the terms "a" or "an", "one or more" and "at least one" can be used interchangeably herein. It is also to be noted that the terms "comprising," "including," and "having" can be used interchangeably. Furthermore, a compound "selected from the group consisting of" refers to one or more of the compounds in the list that follows, including mixtures (i.e. combinations) of two or more of the compounds. According to the present invention, an isolated or biologically pure bioactive agent is a compound that has been removed from its natural milieu. As such, "isolated" and "biologically pure" do not necessarily reflect the extent to which the compound has been purified. An isolated compound of the present invention can be obtained from its natural source, can be produced using molecular biology techniques or can be produced by chemical synthesis.

Reference will now be made in detail to certain embodiments of the invention, examples of which are illustrated in the accompanying figure and Examples section.

Disclosed are the components used to prepare the controlled release compositions of the present invention. These and other materials are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these materials are disclosed that while specific reference of each various individual and collective permutation of these compounds may not be explicitly disclosed, each is specifically contemplated and described herein. For example, if a number of bioactive agents are disclosed and discussed and a number of modifications that can be made to a number of molecules including bioactive agents are discussed, specifically contemplated is each and every combination and permutation of bioactive agent and the modifications that are possible unless specifically indicated to the contrary. Thus, if a class of molecules A, B, and C are disclosed as well as a class of molecules D, E, and F and an example of a combination molecule, A-D is disclosed, then even if it is not individually recited each is individually and collectively contemplated meaning combinations, A-E, A-F, B-D, B-E, B-F, C-D, C-E and C-F are considered disclosed. Likewise, any subset or combination of these is also disclosed. Thus, for example, the sub-group of A-E, B-F, and C-E would be considered disclosed. This concept applies to all aspects of this application including, but not limited to, steps in methods of making and using the present invention.

## **Bioactive Agents**

In one embodiment of the present invention, the bioactive agents are selected from the group consisting of proteins, nucleic acids, carbohydrates, peptides or a small molecule pharmaceutical substances. Proteins of use in the present invention include but are not limited to antibodies, therapeutic proteins, human growth hormone, insulin, oxytocin, octreotide, Gonadotropin-Releasing Hormone, leuprolide, interferon alpha, interferon beta, interferon gamma, insulin, calcitonin, interleukin-1, interleukin-2, and the like. Nucleic acids of use in the present invention include DNA, RNA, chemically modified DNA and chemically modified RNA, aptamers, antisense, RNA interference, and small RNA interference. Carbohydrates include heparin, low molecular weight heparin and the like. Peptides include LHRH agonists and synthetic analogs, leuprolide, somatostatin analogs, hormones, octreotide, glucagons-like peptide, oxytocin and the like. Small molecule pharmaceutical substances include, but are not limited to, antiinfectives, cytotoxics, antihypertensives, antifungal agents, antipsychotics, antidiabetic agents, immune



stimulants, immune suppressants, antibiotics, antivirals, anticonvulsants, antihistamines, cardiovascular agents, anticoagulants, hormones, antimalarials, analgesics, anesthetics, steroids, nonsteroidal anti-inflammatories, antiemetics.

5           In another embodiment, the bioactive agent is an immunogen. Such immunogen may be selected from the group consisting of, but not limited to, immunogens for stimulating antibodies against hepatitis, influenza, measles, rubella, tetanus, polio, rabies, and the like.

10           In another embodiment, the bioactive agent is a substance or metabolic precursor capable of promoting growth and survival of cells and tissues or augmenting the functioning of cells. Such substance or metabolic precursor may be selected from the group consisting of, but not limited to, a nerve growth promoting substance such as a ganglioside, a nerve growth factor, and the like; a hard or soft  
15 tissue growth promoting agent such as fibronectin, human growth hormone, a colony stimulating factor, bone morphogenic protein, platelet-derived growth factor, insulin-derived growth factors, transforming growth factor-alpha, transforming growth factor-beta, epidermal growth factor, fibroblast growth factor, interleukin-1, vascular endothelial growth factor, keratinocyte growth factor, dried bone material, and the  
20 like.

          In another embodiment, the bioactive agent is an antineoplastic agent. In a particular embodiment, the antineoplastic agent is selected from the group consisting of, but not limited to, methotrexate, 5-fluorouracil, adriamycin, vinblastin, cisplatin,  
25 tumor-specific antibodies conjugated to toxins, tumor necrosis factor, and the like.

          In other embodiments, the bioactive agent is selected from the group consisting of, but not limited to, antihistamines such as diphenhydramine, and the like; cardiovascular agents such as papverine, streptokinase and the like; anti-ulcer  
30 agents such as isopropamide iodide, and the like; bronchodilators such as metaproterenol sulfate, aminophylline, and the like; vasodilators such as theophylline, niacin, minoxidil, and the like; central nervous system agents such as tranquilizers, B-adrenergic blocking agents, dopamine, and the like; antipsychotic agents such as risperidone, narcotic antagonists such as naltrexone, naloxone, buprenorphine; and  
35 other like substances.

In a certain embodiment, the bioactive agent is capable of providing a local or systemic biological, physiological or therapeutic effect in the biological system in which it is applied. For example, the agent may act to control infection or inflammation, enhance cell growth and tissue regeneration, control tumor growth and enhance bone growth, among other functions.

In another embodiment, controlled release compositions may contain combinations of two or more bioactive agents. In a particular embodiment, controlled release compositions contain five or fewer bioactive agents. In another particular embodiment, controlled release compositions contain one bioactive agent.

In a particular embodiment, the bioactive agent is in the form of a complex with an organic ion.

In another embodiment, bioactive agents of the present invention may include various salt forms and derivatives including covalent linkages to hydrophilic polymers such as poly(ethylene glycol) and poly(propylene glycol).

The present invention includes pharmaceutical equivalents of bioactive agents. Pharmaceutical equivalents demonstrate similar or greater *in vitro* activity to the bioactive agent itself. In a particular example, a pharmaceutical equivalent may have a similar chemical structure to the bioactive agent, contain only the biologically active portion of the bioactive agent or be a synthetic analog of the bioactive agent.

In a particular embodiment, the bioactive agent has the potential to exhibit at least one positive or negative charge or both positive and negative charge.

In a particular embodiment, the bioactive agent is water soluble.

In another particular embodiment, the bioactive agent is solubilized in an organic solvent, optionally including a cosolvent. The bioactive agent may be soluble in water or in organic solvents or both.

It will be appreciated by one skilled in the art that the actual amounts of bioactive agents to utilize in a particular case will vary according to the specific compound being utilized, the particular compositions formulated, the mode of application, and the particular situs and patient being treated. Dosages for a given host can be determined using conventional considerations, for example, by

customary comparison of the differential activities of the subject compounds and of a known bioactive agent, for example, by means of an appropriate conventional pharmacological protocol. Physicians and formulators, skilled in the art of determining doses of pharmaceutical compounds, will have no problems determining  
5 dose according to standard recommendations.

### **Organic Ion**

Organic ions of use in the present invention include anionic and cationic materials. Anionic materials include, but are not limited to, the following organic acids and their salts: pamoic, dodecylsulfuric, cholic, trifluoromethyl-p-toluic, 2-  
10 naphthalene sulfonic, 2,3-naphthalene dicarboxylic, 1-hydroxy-2-naphthoic, 3-hydroxy-2-naphthoic, 2-naphthoic, and salicylsalicylic. In addition organic forms of sulfates, sulfonates, phosphates, and phosphonates are suitable organic ions. Salt forms of the anionic materials may include sodium, ammonium, magnesium, calcium and the like.

15 Cationic molecules include, but are not limited to, those having an ammonium or guanidinium group or a substituted ammonium group. Organic anionic agents are used with bioactive agents that have one or more functional groups having, or capable of adopting, a positive charge, such as an ammonium or guanidinium group. Organic cationic agents can be used with bioactive agents that have one or more  
20 functional groups having or capable of adopting a negative charge such as a carboxyl, sulfate, sulfonate, phosphate, or phosphonate group.

Organic ion agents of use in the present invention may be soluble in water and in the organic phase to the extent required to enhance encapsulation efficiency and drug loading. In a particular embodiment, enhanced encapsulation efficiency  
25 and drug loading are achieved via decreased degradation of the bioactive agent. In a particular embodiment, the concentration of the organic ion agent in the aqueous phase ranges from about 0.5 to 100 mM. In another particular embodiment, the organic ion ranges from about 5 to 40 mM.

### **Biodegradable Microparticles**

30 In certain embodiments, the controlled release composition is a microparticle.

In certain embodiments, a bioactive agent is associated with a biodegradable polymer in a microparticle form. In a particular embodiment, a microparticle has a diameter less than 1.0 mm and typically between 1.0 and 200.0 microns. Microparticles include both microspheres and microcapsules, and may be

5 approximately spherical or have other geometries. Microspheres are typically approximately homogeneous in composition and microcapsules comprise a core of a composition distinct from a surrounding shell. For purposes of this disclosure, the terms microsphere, microparticle and microcapsule are used interchangeably.

In certain embodiments, microparticles can be made with a variety of

10 biodegradable polymers. Suitable biocompatible, biodegradable polymers include, for example, poly(lactide)s, poly(glycolide)s, poly(lactide-co-glycolide)s, poly(lactic acid)s, poly(glycolic acid)s, poly(lactic acid-co-glycolic acid)s, polycaprolactone, polycarbonates, polyesteramides, polyanhydrides, poly(amino acids), polyorthoesters, polyacetyls, polycyanoacrylates, polyetheresters, poly(dioxanone)s,

15 poly(alkylene alkylate)s, copolymers of polyethylene glycol and poly(lactide)s or poly(lactide-co-glycolide)s, biodegradable polyurethanes, blends and copolymers thereof.

In a particular embodiment, the microparticle is made of poly(d,l-lactide-co-glycolide) (PLGA). PLGA degrades when exposed to physiological pH and

20 hydrolyzes to form lactic acid and glycolic acid, which are normal byproducts of cellular metabolism. The disintegration rate of PLGA polymers will vary depending on the polymer molecular weight, ratio of lactide to glycolide monomers in the polymer chain, and stereoregularity of the monomer subunits. Mixtures of L and D stereoisomers that disrupt the polymer crystallinity will increase polymer

25 disintegration rates. In addition, microspheres may contain blends of two or more biodegradable polymers, of different molecular weight and/or monomer ratio.

In other alternative embodiments, derivatized biodegradable polymers, including hydrophilic polymers attached to PLGA, can be used to form microspheres. In particular embodiments, the hydrophilic polymer is selected from the group

30 consisting of, but not limited to, poly(ethylene glycol), poly(propylene glycol) and copolymers of poly(ethylene glycol) and poly(propylene glycol).

### Biodegradable Nanoparticles

In certain embodiments, the controlled release composition is a nanoparticle.

In certain embodiments, the bioactive agent, with or without a hydrophilic polymer attached, is associated with biodegradable submicron particles for controlled  
5 release of the bioactive agent. A nanoparticle has a diameter ranging from 20.0 nanometers to about 2.0 microns and is typically between 100.0 nanometers and 1.0 micron.

Nanoparticles can be created in the same manner as microparticles, except that high-speed mixing or homogenization is used to reduce the size of the  
10 polymer/bioactive agent emulsions to less than 2.0 microns and typically below 1.0 micron. Alternative methods for nanoparticle production are known in the art and may be employed for the present invention.

### Production of Controlled Release Compositions

In one embodiment an organic phase, containing one or more solvents, a  
15 bioactive agent and a polymer is contacted with an aqueous phase, containing an organic ion. In a particular embodiment, the organic phase additionally includes a cosolvent. In another particular embodiment, the aqueous phase additionally includes an emulsifying agent. In another particular embodiment, the organic ion is a salt of an organic acid.

20 In another embodiment, the organic phase is contacted with the aqueous phase to form an emulsion wherein the emulsion comprises droplets of the organic phase dispersed in the aqueous phase. Solvent is subsequently removed from the emulsion droplets to form hardened microparticles. In a particular embodiment, the solvent is removed by evaporation. In another particular embodiment, the solvent is  
25 removed by extraction into an extraction liquid; for example, the extraction liquid may be water. In yet another a particular embodiment, the solvent is removed by filtration. The hardened microparticles may then be recovered from the aqueous phase and dried.

In yet another embodiment, the emulsion is produced by stirring the organic  
30 and aqueous phases. In another embodiment, the emulsion is produced by use of a mixer. In a particular embodiment, the mixer is a static mixer. In a certain

embodiment the emulsion is produced by use of turbulent mixing. In another embodiment the emulsion is produced without turbulent mixing.

The emulsion process may be carried out at any temperature between the boiling point and freezing point of the components. In one embodiment, the temperature ranges from about 0°C to about 100°C and is typically between 5°C and 75°C. In a particular embodiment, the emulsion process is carried out between about 15°C to about 60°C.

The organic phase of the present invention may contain solvents including, but not limited to, methylene chloride, ethyl acetate, benzyl alcohol, acetone, acetic acid, propylene carbonate and other solvents in which the biodegradable polymer is soluble. In a particular embodiment, the solvent of the organic phase may be selected from the group consisting of ethyl acetate and methylene chloride.

In a particular embodiment, the aqueous phase may include water and an emulsifier.

In a certain embodiment, cosolvents may be added to the organic phase. They are optionally used to promote solubility of the bioactive agent in the organic phase. In a particular embodiment, they are selected from the group consisting of, but not limited to, dimethyl sulfoxide, dimethyl formamide, n-methylpyrrolidinone, PEG<sub>200</sub>, PEG<sub>400</sub>, methyl alcohol, ethyl alcohol, isopropyl alcohol, and benzyl alcohol. In another particular embodiment, the cosolvent may be present between 0 and 90% w/w of the solvent of the organic phase. In another particular embodiment, the cosolvent is present between 0 and 50% w/w of the solvent of the organic phase. The bioactive agent may be dissolved first in an appropriate volume of the cosolvent which is then added to the solvent of the organic phase, optionally having the biodegradable polymer dissolved therein, so as to form a solution of all the components of the organic phase. A person of ordinary skill can adjust the volumes and order of addition to achieve the desired solution of bioactive agent and biodegradable polymer. In a certain embodiment, the bioactive agent will be present in the organic phase at a concentration of 1 – 20% w/w. In a particular embodiment, the biodegradable polymer will be present in the organic phase at a concentration of 2-40% w/w. In another particular embodiment, the biodegradable polymer will be present in the organic phase at a concentration of 5-20% w/w.

Organic ions are dissolved in the aqueous phase. In a certain embodiment, they are dissolved at a concentration of between about 0.1 mM to about 1000 mM. In a particular embodiment, they are dissolved at a concentration of between 1 to 100 mM. The concentration may be adjusted for each particular organic ion agent and  
5 bioactive agent to achieve the desired drug loading and encapsulation efficiency.

One or more emulsifying agents may be added to the aqueous phase to stabilize the emulsion. Emulsifying agents may be selected from the group consisting of, but not limited to, poly(vinyl alcohol), albumin, lecithin, vitamin E TPGS and polysorbates. The emulsifying agents are present at a concentration in the  
10 aqueous between 0 and 10% (w/w). In a particular embodiment, they are present at a concentration between 0.5 to 5% w/w.

Organic anions of the present invention include, but are not limited to, the following organic acids and their salts: pantoic, dodecylsulfuric, cholic, trifluoromethyl-p-toluic, 2-naphthalene sulfonic, 2,3-naphthalene dicarboxylic, 1-  
15 hydroxy-2-naphthoic, 3-hydroxy-2-naphthoic, 2-naphthoic, and salicylsalicylic or organic derivatives of sulfates, sulfonates, phosphates, and phosphonates.

### Pharmaceutical Formulations

In addition to the compounds formulated for parenteral administration, such as intravenous or intramuscular injection, other alternative methods of administration  
20 of the present invention may also be used, including but not limited to intradermal administration, pulmonary administration, buccal administration, transdermal and transmucosal administration. Transmucosal administration may include, but is not limited to, ophthalmic, vaginal, rectal and intranasal. All such methods of administration are well known in the art.

25 In a particular embodiment, the controlled release composition of the present invention may be administered intranasally, such as with nasal solutions or sprays, aerosols or inhalants. Nasal solutions are usually aqueous solutions designed to be administered to the nasal passages in drops or sprays. Nasal solutions are prepared so that they are similar in many respects to nasal secretions. Thus, the aqueous nasal  
30 solutions usually are isotonic and slightly buffered to maintain a pH of 5.5 to 6.5.

Antimicrobial preservatives, similar to those used in ophthalmic preparations, and appropriate drug stabilizers, if required, may be included in any of the formulations.

Preservatives and other additives may be selected from the group consisting of, but not limited to, antimicrobials, anti-oxidants, chelating agents, inert gases and the like. Various commercial nasal preparations are known and include, for example, antibiotics and antihistamines and are used for asthma prophylaxis.

5           In another embodiment, controlled release compositions of the present invention are applied topically. Such controlled release compositions include, but are not limited to, lotions, ointments, creams, gels, drops, suppositories, sprays, liquids and powders. Conventional pharmaceutical carriers, aqueous, powder or oily bases, thickeners and the like may be necessary or desirable.

#### 10           **Excipients, Carriers and Diluents**

Controlled release compositions of the present invention can be formulated in any excipient the biological system or entity can tolerate. Examples of such excipients include water, saline, Ringer's solution, dextrose solution, Hank's solution and other aqueous physiologically balanced salt solutions. Nonaqueous vehicles, such as fixed  
15       oils, polyethylene glycol and injectable organic esters such as ethyl oleate may also be used. Other useful formulations include suspensions containing viscosity-enhancing agents, such as sodium carboxymethylcellulose, sorbitol or dextran.

Excipients can also contain minor amounts of additives, such as substances that enhance isotonicity and chemical stability. Examples of buffers include phosphate  
20       buffer, bicarbonate buffer and Tris buffer, while examples of preservatives include thimerosal, cresols, formalin and benzyl alcohol.

Pharmaceutical carriers for controlled release compositions of the present invention are known to those skilled in the art. Those most typically utilized are likely to be standard carriers for administration to humans including solutions such as sterile  
25       water, saline and buffered solutions at physiological pH.

The controlled release compositions of the present invention may be suspended in any aqueous solution or other diluent for injection in a human or animal patient in need of treatment. Aqueous diluent solutions may further include a viscosity enhancer selected from the group consisting of sodium  
30       carboxymethylcellulose, sucrose, mannitol, dextrose, trehalose and other biocompatible viscosity enhancing agents. The viscosity may be adjusted to a value between 2 centipoise (cp) and 100 cp, preferably between 4 and 40 cp.



In a particular embodiment, a surfactant may be included in the diluent to enhance suspendability of the controlled release composition. Surfactants may be selected from the group consisting of, but not limited to, polysorbates and other biocompatible surfactants. Surfactants are used at a concentration of between 0 and 5 5% (w/w), preferably between 0.1 and 1% w/w.

## EXAMPLES

The following examples are included to demonstrate particular embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventors to function well in the practice of the invention, and thus can be considered to constitute particular modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

### Example 1

**Conventional Preparation of Octreotide Acetate Encapsulated in Poly(lactide-co-glycolide) (PLGA) Microparticles Using Co-Solvents According to Previously Used Methods.**

Octreotide acetate microparticle formulations were prepared to investigate the effect of different co-solvents in the organic phase. Formulations A-F were prepared using an oil-in-water emulsion/solvent extraction technique, are summarized in Table 1. PLGA polymer (50:50 lactide/glycolide, MW 24,000, 180 mg) was dissolved in ethyl acetate (EtOAc, 900  $\mu$ L), and octreotide acetate (20 mg) dissolved in a co-solvent (Table 1) was added to the polymer solution. The resulting homogeneous organic phase was added to an aqueous phase (2 mL) containing 1% poly(vinyl alcohol) (PVA) and the mixture was vortexed for 15-30 seconds. The emulsion was poured into a solvent extraction solution (10 mM sodium phosphate, pH 8.0, 150 mL) and stirred for four hours to extract EtOAc. Particles were isolated by filtration, washed with water and air dried overnight. The formulations were characterized by particle size, scanning electron microscopy (SEM), morphology, octreotide core load and *in vitro* release profiles.

Formulation D was repeated using an emulsifying device, such as that disclosed in PCT Application Serial No. PCT/US04/11485, that combined a homogeneous organic phase (2 mL) consisting of octreotide acetate (20 mg), MeOH (100 $\mu$ L), PLGA polymer (50:50 lactide/glycolide, MW 24,000, 180 mg) and EtOAc (1.9 mL) with a 1% PVA aqueous phase (4 mL). The emulsion was then added to a

solvent extraction solution and stirred for four hours to extract EtOAc. This process produced formulation D2 (Table 1).

5 The co-solvents investigated had a small influence on particle size and core load. Particle sizes were larger with the higher viscosity poly(ethylene glycol) (PEG) co-solvents. In contrast, core loads were similar for the methanol (MeOH) and PEG co-solvents (formulations A-C). The highest core loads were obtained for the MeOH cosolvent with a pH 8 buffered emulsion step (formulation D2) and for the dimethyl sulfoxide (DMSO) cosolvent (formulation F).

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*In vitro* release kinetics were measured in either phosphate buffered saline (PBS, pH 7.2, 37°C) or 100 mM sodium acetate (NaOAc, pH 4.0, 37°C). An example is shown in Table 2 (Formulation D2). The PEG co-solvent systems showed the highest initial peptide burst (8-10%), while the remaining formulations had an initial  
15 burst in the range of 2-3%. All the formulations released peptide for at least 6 weeks although there was a decrease in the relative release rates for formulations prepared with polar aprotic solvents (formulations E - F) resulting in lower total release of peptide relative to the other formulations.

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Octreotide acetate as the free peptide was measured to be 95% intact by high-pressure liquid chromatography (HPLC) following incubation in the release medium (PBS, pH 7.2, 37°C) after 49 days. In contrast, incubation of octreotide acetate PLGA microparticle formulations produced 55% of modified peptide species after 70 days in the release medium (PBS, pH 7.2, 37°C, Table 2). HPLC analysis  
25 showed that the new peptide entities were more hydrophobic than native octreotide acetate. HPLC/MS analysis revealed masses consistent with acylation of the parent peptide by PLGA polymer. The masses found were consistent with random acylation, for example, peptide plus one or two glycolic or lactic acid monomers in any combination. It may be that acylation products arise from attack on PLGA  
30 fragments or the polymer backbone by nucleophilic moieties in octreotide. At a lower pH these moieties likely would be protonated reducing their nucleophilicity and consequently the amount of acylated product. It was observed that formation of acylated byproducts for octreotide acetate PLGA microparticles incubated in 100 mM sodium acetate (NaOAc, pH 4.0) buffer was reduced to 1.25% at 49 days, in marked  
35 contrast to the results for PBS buffer (55%).

**Table 1.** Octreotide Acetate Encapsulation in PLGA Microparticles.

	<i>Co-solvent in organic phase</i>	<i>Composition of Aqueous Phase</i>	<i>Median particle size</i>	<i>Core load (encaps. eff.)</i>	<i>Burst (%)</i>	<i>Total Peptide Release (Acyalted)</i>
A	PEG <sub>200</sub> (100 µL)	1% PVA	49 µm	2.83% (28%)	7.96	72.6% (44%)
B	PEG <sub>400</sub> (100 µL)	1% PVA	76 µm	3.20% (32%)	10.4	63.0% (48%)
C	MeOH (50 µL)	1% PVA	25 µm	2.75% (28%)	2.91	65.7% (50%)
D	MeOH (100 µL)	1% PVA + 10 mM PO <sub>4</sub> (pH8)	34 µm	5.57% (56%)	2.58	65.1% (50%)
D2	MeOH (100 µL)	1% PVA + 10 mM PO <sub>4</sub> (pH8)	60 µm	5.66% (57%)	1.90	85.8% (55%)
E	DMF (100 µL)	1% PVA	38 µm	3.41% (34%)	1.97	50.3% (33%)
F	DMSO (100µL)	1% PVA	38 µm	4.88% (49%)	2.74	43.4% (36%)

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**Table 2.** *In vitro* release of formulations D2 and AG. NaOAc buffer contains 100 mM NaOAc (pH 4.0), 0.02% Tween-20 and 0.05% NaN<sub>3</sub>. PBS is phosphate buffered saline (pH 7.2) containing 0.02% Tween-20 and 0.05% NaN<sub>3</sub>. Samples were incubated in a shaking (150 Hz) water bath incubator at 37C. Peptide and acylated peptide release values are listed as cumulative percent released.

<b>Formulation D2</b>		
<b>100 mM NaOAc (pH 4)</b>		
<b>Day</b>	<b>% Peptide Released</b>	<b>% Acylated Peptide Released</b>
<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>1</b>	<b>5.55</b>	<b>0.15</b>
<b>3</b>	<b>13.75</b>	<b>0.78</b>
<b>6</b>	<b>53.47</b>	<b>4.11</b>
<b>10</b>	<b>71.74</b>	<b>5.16</b>
<b>14</b>	<b>72.19</b>	<b>5.26</b>
<b>20</b>	<b>72.21</b>	<b>5.28</b>
<b>24</b>	<b>72.22</b>	<b>5.30</b>
<b>29</b>	<b>72.22</b>	<b>5.30</b>
<b>34</b>	<b>72.22</b>	<b>5.30</b>
<b>42</b>	<b>72.22</b>	<b>5.30</b>
<b>48</b>	<b>72.22</b>	<b>5.30</b>

Formulation D2		
PBS (pH 7)		
Day	% Peptide Released	% Acylated Peptide Released
0	0.0	0.0
1	1.81	0.08
3	3.09	0.22
6	4.87	0.59
10	7.54	1.98
14	10.42	4.29
20	17.81	10.51
24	20.69	14.06
29	23.86	18.86
34	26.21	23.12
42	32.91	28.73
48	35.13	32.14
57	36.50	35.10
64	37.83	37.41
71	38.42	45.82
78	38.58	46.37
85	38.64	46.70

<b>Formulation AG</b>		
<b>PBS (pH 7)</b>		
<b>Day</b>	<b>% Peptide Released</b>	<b>% Acylated Peptide Released</b>
<b>0</b>	<b>0.0</b>	<b>0.0</b>
<b>1</b>	<b>8.04</b>	<b>0.33</b>
<b>2</b>	<b>9.09</b>	<b>0.47</b>
<b>6</b>	<b>12.27</b>	<b>0.65</b>
<b>15</b>	<b>17.75</b>	<b>1.23</b>
<b>24</b>	<b>20.03</b>	<b>1.78</b>
<b>29</b>	<b>23.78</b>	<b>2.66</b>
<b>35</b>	<b>36.16</b>	<b>5.62</b>
<b>42</b>	<b>43.80</b>	<b>8.15</b>
<b>49</b>	<b>51.17</b>	<b>11.13</b>
<b>57</b>	<b>61.47</b>	<b>15.57</b>
<b>64</b>	<b>67.63</b>	<b>18.16</b>

**Example 2****Production of Water Insoluble Organic Acid Salts (Complexes) of Octreotide and Encapsulation in PLGA Microparticles According to Previously Used Methods.**

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Organic ion agents were investigated where the organic ion was initially complexed with octreotide acetate to form a water insoluble salt followed by encapsulation in PLGA microparticles.

10            Sodium Dodecylsulfate (SDS).            An octreotide-SDS complex was prepared by dissolving octreotide acetate (100 mg) in H<sub>2</sub>O (500 µL). SDS (1.5 equiv, 43.2 mg) dissolved in H<sub>2</sub>O (500 µL) was added drop wise to the octreotide acetate solution with vortexing at room temperature. A precipitate immediately formed. The sample was centrifuged at 10,000 rpm for 1 minute and the supernatant removed by  
15            pipette. The precipitate was washed with cold water and lyophilized providing an octreotide-SDS complex (95.3 mg). RP-HPLC analysis showed a pronounced broadening of the octreotide peak indicating formation of the octreotide/SDS complex. Formulations G-I were prepared using an oil-in-water emulsion/solvent extraction technique. PLGA polymer (MW 24,000, 180 mg) was dissolved in EtOAc  
20            (900 µL). Octreotide/SDS complex was dissolved in MeOH (100 µL) and added to the polymer solution. This resulted in a heterogeneous organic phase. In the case of formulation I (Table 3) an additional aliquot of MeOH (100 µL) was added to produce a homogeneous organic phase. The resulting organic phase was added to an aqueous phase (2 mL) containing 1% PVA and the mixture was vortexed for 15 - 30  
25            seconds. The emulsion was poured into a solvent extraction solution (10 mM sodium phosphate, pH 8.0, 150 mL) and stirred for four hours to extract EtOAc. Particles were isolated by filtration, washed with water and air dried overnight. The formulations were characterized by particle size, SEM morphology, octreotide core load and *in vitro* release profiles.

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The measured core load for formulations G-I prepared from the octreotide-SDS complex were relatively low, between 0.6-2.6% (Table 3). Also the median particle size was reduced by approximately 40% relative to formulations (A-F) prepared with octreotide acetate.

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The *in vitro* release profiles of formulations G-I in PBS were quite similar. Each had an initial burst of approximately 20% followed by three weeks of 1.5% release/week. After three weeks the rate of release increased to approximately 7.0 % release/week, culminating in approximately 80% total peptide release at 9 weeks.

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The *in vitro* PBS release assay with these formulations resulted in the release of similar amounts of acylated (40-55%) and total peptide compared to octreotide acetate (formulations A-F).

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**Table 3.** Octreotide-SDS Complex in the Organic Phase.

<i>Formulation</i>	<i>Co-solvent in Organic Phase</i>	<i>Median particle size</i>	<i>Core load (encaps. eff.)</i>	<i>Burst (Acylated)</i>
G	MeOH (100 $\mu$ L)	11.4 $\mu$ m	0.61% (6.1%)	20.3% (49%)
H	MeOH (100 $\mu$ L)	12.4 $\mu$ m	0.75% (7.5%)	21.2% (40%)
I	MeOH (200 $\mu$ L)	12.9 $\mu$ m	2.64% (2.6%)	20.2% (42%)

Benzoic Acid. Formulations (J-M) were prepared using one to ten equivalents of benzoic acid co-dissolved in the organic phase with PLGA. PLGA polymer (MW 24,000, 180 mg) and benzoic acid (2.4 – 24 mg) were dissolved in EtOAc (900  $\mu$ L). Octreotide acetate was dissolved in MeOH (100  $\mu$ L) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was added to an aqueous phase (2 mL) containing 1% PVA and the mixture was vortexed for 15 - 30 seconds. The emulsion was poured into a solvent extraction solution (10 mM sodium phosphate, pH 8.0, 150 mL) and stirred for four hours to extract EtOAc. Particles were isolated by filtration, washed with water and air dried overnight. The core loads measured between 0.88-1.67% over the range of 1-10 added equivalents of benzoic acid per equivalent of octreotide acetate (Table 4).

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Pamoic Acid.

An octreotide-pamoate complex was prepared by dissolving pamoic acid (19.4 mg, 0.05 mmol) in 0.2 N NaOH (500  $\mu$ L) to provide the sodium pamoate salt. Octreotide acetate (100 mg, 0.10 mmol) was dissolved in deionized water (100  $\mu$ L) and added drop wise with gentle vortexing to the sodium pamoate salt solution. This produced a flocculent light yellow precipitate. The precipitate was pelleted by centrifugation, and the supernatant removed by pipette. The pellet was washed with water (1.0 mL), re-suspended in water and lyophilized to a light yellow powder (113 mg). The octreotide/pamoate ratio of this preparation was 1.71 as measured by RP-HPLC.

A second octreotide-pamoate complex was prepared by dissolving pamoic acid (19.4 mg, 0.05 mmol) in 0.4 N NaOH (250  $\mu$ L) and dioxane (250  $\mu$ L) to provide a solution of sodium pamoate in dioxane/water (1:1). Octreotide acetate (50 mg, 0.05 mmol) was dissolved in dioxane/water (1:1, 200  $\mu$ L). The octreotide acetate solution was added drop wise to the sodium pamoate with mixing to provide a light yellow, homogenous solution. This material was lyophilized to dryness providing a light yellow powder (65 mg). The octreotide/pamoate ratio of this preparation was 1.02 as measured by RP-HPLC. These two preparations were used to prepare new PLGA microparticle formulations.

**Table 4.** Benzoic acid and Octreotide Acetate in Organic Phase.

<i>Formulation</i>	<i>Co-solvent in Organic Phase</i>	<i>Benzoic acid : Octreotide acetate ratio</i>	<i>Median particle size</i>	<i>Core load (encaps. eff.)</i>
J	MeOH (100 $\mu$ L)	1	21.8 $\mu$ m	1.36% (14%)
K	MeOH (100 $\mu$ L)	2	19.5 $\mu$ m	0.88% (8.8%)
L	MeOH (100 $\mu$ L)	5	18.8 $\mu$ m	1.61% (16%)
M	MeOH (100 $\mu$ L)	10	17.9 $\mu$ m	1.67% (17%)

Microparticle formulations (Table 5, Q-W) were prepared by an oil-in-water emulsion/ solvent extraction method. PLGA polymer (MW 24,000, 180 mg) was

dissolved in EtOAc (1000  $\mu$ L). Octreotide pamoate (20 or 40 mg) was dissolved in benzyl alcohol (BnOH, 1000  $\mu$ L) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase in a ratio of 1:2 to provide an emulsion. The emulsion was  
5 collected directly into a 0.3% PVA solvent extraction solution (150 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C.

Formulation characterization (Table 5) revealed that the initial  
10 octreotide/pamoate ratio of 1.7 had little effect on the encapsulation efficiency and core load relative to the formulations prepared with the octreotide/pamoate ratio of 1.02. In contrast, changing the co-solvent to benzyl alcohol increased the encapsulation efficiency by approximately 60% relative to methanol (e.g. Formulation S compared to T).

15 The *in vitro* release profiles of these formulations in PBS demonstrated total peptide released (79-92%, Table 5 Q-T) is comparable to PLGA octreotide acetate microparticles made by conventional methods (formulations D, F, Table 1) while the amount of acylated peptide released (28-40%, Table 5 Q-T) is decreased slightly  
20 relative to conventional formulations (44-55%, Table 1, A-D).

Formulations prepared using the octreotide/pamoate ratio of 1:1 did not show as strong a dependence of encapsulation efficiency and core load on the nature of the co-solvent as the 1.7 ratio formulations above. The differences in solubility for  
25 the complexes with different octreotide/pamoate ratios in the co-solvent is proposed as an explanation for this observation. The higher octreotide/pamoate ratio material had an increased solubility in benzyl alcohol relative to methanol resulting in higher encapsulation efficiency. In contrast, it was found that there was no significant difference in solubility in methanol versus benzyl alcohol for the 1:1  
30 octreotide/pamoate complex. This resulted in similar encapsulation efficiencies and core loads independent of the co-solvents.

The *in vitro* release profiles of these 1:1 formulations (U-W) reveal similar trends as discussed above, namely, that the total percent of peptide released (85 –  
35 110%, Table 5 U-W) is again comparable to conventional formulations (Example 1)

(ca. 85%, Table 2) while the amount of acylated product released (35 – 44% Table 5 U-W) is decreased somewhat relative to conventional formulations (44-55%, Table 1, A-D2).

- 5            Analysis of the final octreotide/pamoate molar ratio showed a wide variation among the formulations tested (Table 5) with a range from 2.1:1 (formulation W) to over 200:1 (formulation R). In all cases the ratio is more than twice the octreotide/pamoate ratio of the starting peptide salt complex. Thus the use of a preformed pamoate salt of the peptide octreotide yielded highly variable
- 10    octreotide/pamoate molar ratios in the final sustained release formulation.

**Table 5.** Octreotide-Pamoate Microparticles Prepared Using Pre-Formed Complex.

<i>Formulation</i>	<i>Octreotide/ pamoate ratio initial (final)</i>	<i>Co-solvent in Organic Phase</i>	<i>Median particle size</i>	<i>Core load (encap eff)</i>	<i>Total Peptide Release (Acylated)</i>
Q	1.7:1 (4.4:1)	MeOH (100 $\mu$ L)	40 $\mu$ m	6.52% (65%)	88.6% (28.1%)
R	1.7:1 (201:1)	MeOH (500 $\mu$ L)	34 $\mu$ m	3.34% (33%)	79.2% (38.9%)
S	1.7:1 (13:1)	BnOH (200 $\mu$ L)	31 $\mu$ m	8.29% (83%)	87.2% (39.7%)
T	1.7:1 (21:1)	MeOH (200 $\mu$ L)	37 $\mu$ m	5.03% (50%)	91.5% (32.2%)
U	1:1 (5.3:1)	MeOH (200 $\mu$ L)	48 $\mu$ m	4.93% (49%)	92.3% (37.3%)
V	1:1 (5.4:1)	BnOH (200 $\mu$ L)	48 $\mu$ m	4.76% (48%)	110% (44.4%)
W	1:1 (2.1:1)	BnOH (200 $\mu$ L)	44 $\mu$ m	5.01% (25%)	84.9% (35.0%)

### 5            **Example 3**

#### **Octreotide Acetate Encapsulation in PLGA Microspheres Using Organic Acid Salts in the Aqueous Emulsion Phase According to the Present Invention.**

10            Surprisingly it was discovered that the use of an organic acid salt in the aqueous phase of the emulsification process allowed use of a water soluble peptide and eliminated the need to prepare complexed species in an independent step prior to preparing the formulation. The present invention provided added benefits such as increased drug coreload, consistent octreotide/organic ion ratio, and decreased peptide degradation during *in vitro* release.

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              Microparticle formulations were prepared by an oil-in-water emulsion/solvent extraction method. PLGA polymer (MW 24,000, 140 -180 mg) was dissolved in EtOAc (1000  $\mu$ L). Octreotide acetate (20 -60 mg) was dissolved in BnOH (1000  $\mu$ L)

and added to the polymer solution yielding a homogenous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10-50 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (150 mL) and stirred for four  
5 hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This resulted in a final octreotide/pamoate ratio of approximately 1-1.5 in the microparticle formulation measured by RP-HPLC (Table 6).

10 The effects of various experimental parameters on core load were investigated including organic to aqueous phase ratio, nature of co-solvent, and volume of co-solvent. BnOH was found to be a more suitable co-solvent than MeOH. It was possible to use BnOH in larger volumes than MeOH, as MeOH induced polymer precipitation in the organic phase. BnOH also led to a small increase in core  
15 load versus MeOH (Formulation Y, AB, Table 6). However, the use of BnOH without the organic ion in the aqueous phase did not provide high core loads or encapsulation efficiencies (AI, Table 6). It was also found that increasing the aqueous to organic phase ratio increased the encapsulation efficiency slightly when BnOH was used as the co-solvent (Formulations AE, AF, Table 6). In all cases the  
20 molar ratio of octreotide to pamoate was tightly grouped between 1.0 and 1.5, in contrast to the formulations of Example 2 (Table 5) where the use of a preformed octreotide/pamoate complex led to wide variations of the final octreotide/pamoate ratio from 2.1 to over 200.

25 Significantly, product with predictable and elevated drug core loads ranging from 5-17.5% could be formed with the method of the present invention, (formulations AD, AG, AH, Table 6), in contrast to the prior art methods of Examples 1 and 2 where the maximum drug core load achieved was about 8% (Table 5 - S) with averages ranging from 2-6% (Tables 1-5). In addition, the compositions of the  
30 present invention have consistent stoichiometry for the molar ratio of bioactive agent to organic ion (Table 6). This is in contrast to the compositions made using previous methods (Table 5). Furthermore, the relative production of acylated peptide is lower for microparticles made with the organic ion in the aqueous phase (Table 2, Table 6) than for microparticles made with the use of preformed octreotide-pamoate (Table 5)  
35 or octreotide acetate (Table 2).

**Table 6.** Octreotide-Pamoate Complex Microparticles by an *in situ* Process.

<i>Formulation (Octreotide/ pamoate final ratio)</i>	<i>Octreotide acetate input</i>	<i>Co- solvent</i>	<i>Organic/ Aqueous phase ratio</i>	<i>Median particle size</i>	<i>Core load (encap eff)</i>	<i>Total Peptide Release (Acyalted)</i>
X (1.09:1)	40 mg	MeOH (200 $\mu$ L)	1:4	79 $\mu$ m	8.52% (46.8%)	98.8% (15.7%)
Y (0.86:1)	20 mg	MeOH (200 $\mu$ L)	1:10	71 $\mu$ m	5.13% (51%)	120% (30.6%)
Z (1.09:1)	20 mg	BnOH (1000 $\mu$ L)	1:2	44 $\mu$ m	7.61% (76%)	97.1% (4.11%)
AA (1.01:1)	20 mg	BnOH (1000 $\mu$ L)	1:2	59 $\mu$ m	6.79% (6.8%)	101% (12.7%)
AB (1.11:1)	20 mg	BnOH (500 $\mu$ L)	1:2	45 $\mu$ m	6.19% (62%)	97.1% (14.8%)
AC (1.14:1)	20 mg	BnOH (1000 $\mu$ L)	1:2	47 $\mu$ m	7.51% (75%)	96.8% (13.4%)
AD (1.11:1)	40 mg	BnOH (1000 $\mu$ L)	1:2	53 $\mu$ m	12.7% (64%)	101% (16.1%)
AE (1.41:1)	60 mg	BnOH (500 $\mu$ L)	1:2	45 $\mu$ m	9.51% (32%)	103% (26.1%)
AF (1.16:1)	60 mg	BnOH (500 $\mu$ L)	1:4	50 $\mu$ m	12.0% (40%)	108% (21.7%)
AG (1.39:1)	60 mg	BnOH (1000 $\mu$ L)	1:2	39 $\mu$ m	17.2% (57%)	92.5% (20.7%)
AH (1.36:1)	60 mg	BnOH (1000 $\mu$ L)	1:2	37 $\mu$ m	17.5% (57%)	111% (25.0%)
AI	60 mg	BnOH (1000 $\mu$ L)	1:2	40 $\mu$ m	6.85% (23%)	ND

The effect of organic acid concentration in the aqueous phase was explored to determine the optimal manufacturing parameters. PLGA polymer (MW 24,000, 160 mg) was dissolved in EtOAc (1000  $\mu$ L). Octreotide acetate (40 mg) was dissolved in BnOH (1000  $\mu$ L) and added to the polymer solution yielding a homogenous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 20 or 50 mM sodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (150 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. Formulations AJ - AL show that 20 or 50 mM disodium pamoate had no effect on core load relative to 10 mM disodium pamoate (Table 7). However, the disodium pamoate concentration in the aqueous phase did have a measurable effect on the "day one" *in vitro* PBS release. The formulation prepared using 50 mM disodium pamoate resulted in a 15% burst (Formulation AL, Table 7) as compared to less than 4% burst for formulations prepared with 20 mM organic ion (Formulations AJ, AK, Table 7). This suggests that excess organic ion in the aqueous phase is deleterious to the *in vitro* release performance of the formulations.

**Table 7.** The effect of organic ion concentration on the formation of octreotide-pamoate microparticles.

<i>Formulation (Octreotide/ pamoate final ratio)</i>	<i>Sodium pamoate conc.</i>	<i>Organic/ Aqueous phase ratio</i>	<i>Median particle size</i>	<i>Core load (encap eff)</i>	<i>PBS Burst Release</i>	<i>Total Peptide Release (Acyated)</i>
AJ (1.33:1)	20 mM	1:1	33 $\mu$ m	13.3% (67%)	3.77%	108% (25.7%)
AK (1.29:1)	20 mM	1:2	41 $\mu$ m	13.3% (67%)	3.38%	106% (22.4%)
AL (1.29:1)	50 mM	1:2	54 $\mu$ m	12.8% (64%)	15.0%	110% (26.8%)

Alternative organic ions in addition to pamoate were investigated to explore the general utility of the present invention. Microparticle formulations were prepared by an oil-in-water emulsion/solvent extraction method. PLGA polymer (MW 24,000, 160 mg) was dissolved in EtOAc (1000  $\mu$ L). Octreotide acetate (40 mg) was



dissolved in BnOH (1000  $\mu$ L) and added to the polymer solution yielding a homogenous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10–20 mM organic acid as its sodium salt to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (150 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This resulted in microparticle formulations with octreotide core loads between 6.8 and 15.3% as measured by RP-HPLC (Table 8). The effects of the tested organic ions on core load are revealing. Formulations AM – AP show no increase in the measured core load relative to control containing sodium pamoate (Formulations AT, AU, AY, Table 8). In contrast formulations AQ-AS, AV-AX and AZ-BB, which employed organic acids ranging from cholic acid to bicyclic aromatics, provided peptide core loads comparable to pamoic acid (Table 8). These results imply that organic acids with appropriate physiochemical properties can be substituted for pamoic acid to produce comparable microparticle formulations.

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**Table 8.** The Effect of Various Organic Acids (Sodium Salts) in the Aqueous Phase on the Formation of Octreotide-Complex Microparticles.

<i>Formulation</i>	<i>Organic acid sodium salt (conc.)</i>	<i>Particle size</i>	<i>Core load (encap eff)</i>	<i>Total Peptide Release (Acyalted)</i>
AM	Succinic (10 mM)	34.1	7.74% (39%)	99.9% (53.4%)
AN	Benzoic (10 mM)	32 $\mu$ m	6.88% (34%)	105% (56.7%)
AO	Salicylic (10 mM)	34 $\mu$ m	7.78% (39%)	106% (54.0%)
AP	Trifluoromethyl -p-toluic (10 mM)	33 $\mu$ m	8.92% (45%)	107% (50.7%)
AQ	Cholic (20 mM)	60 $\mu$ m	13.2% (66%)	104% (47.2%)
AR	2-Naphthalene sulfonic (20 mM)	38 $\mu$ m	11.6% (58%)	110% (42.6%)
AS	2,3-Naphthalene dicarboxylic (10 mM)	38 $\mu$ m	13.1% (66%)	109% (47%)
AT	Pamoic (10 mM)	45 $\mu$ m	13.8 (69%)	98.5% (37%)
AU	Pamoic (10 mM)	43 $\mu$ m	14.2% (71%)	97.5% (31%)
AV	1-Hydroxy-2-naphthoic (20 mM)	42 $\mu$ m	15.3% (76%)	152% (25.7%)
AW	3-Hydroxy-2-naphthoic (20 mM)	40 $\mu$ m	14.6% (72%)	105% (20.8%)
AX	2-Naphthoic (20 mM)	39 $\mu$ m	13.4% (67%)	134% (32.9%)
AY	Pamoic (10 mM)	46 $\mu$ m	14.4% (72%)	103% (22%)
AZ	2-Naphthalene sulfonic (20 mM)	36 $\mu$ m	10.8% (54%)	138% (33.0%)
BA	2,3-Naphthalene dicarboxylic (10 mM)	46 $\mu$ m	12.1% (61%)	97.8% (25%)
BB	Salicylsalicylic (20 mM)	39 $\mu$ m	12.4% (62%)	114% (23.2%)

**Example 4****Encapsulation of Additional Peptides in PLGA Microspheres Using Organic Acid Salts In the Aqueous Emulsion Phase According to the Present Invention.**

5           Oxytocin acetate and leuprolide acetate were formulated in PLGA  
microparticles according to the present invention as described in the examples  
below. The results of these investigations demonstrate the utility of the present  
invention in relation to increased core load and encapsulation efficiency  
(Formulations BI vs BJ-BK and BLvs BM) relative to conventional methodology  
10 (Table 9).

Formulation BI (Leuprolide) – Conventional encapsulation method  
PLGA polymer (MW 24,000, 160 mg) was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (1000 µL). Leuprolide  
acetate (40 mg) was dissolved in BnOH (1000 µL) and added to the polymer solution  
15 yielding a homogeneous organic phase. The resulting organic phase was combined  
with a 1% PVA aqueous phase to provide an emulsion. The emulsion was collected  
directly into a 0.3% PVA solvent extraction solution (150 mL) and stirred for four  
hours to extract EtOAc. Hardened microparticles were collected by filtration, washed  
with water, air dried and stored at 4°C. This provided formulation BI (140 mg, 70.0%  
20 yield) with a median particle size 50.1 µm. The core load (1.99%), encapsulation  
efficiency (9.95%) and *in vitro* burst (1.63%) were determined by RP-HPLC assay.

Formulation BJ (Leuprolide) – Organic ion assisted encapsulation method  
PLGA polymer (MW 24,000, 160 mg) was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (1000 µL). Leuprolide  
25 acetate (40 mg) was dissolved in BnOH (1000 µL) and added to the polymer solution  
yielding a homogeneous organic phase. The resulting organic phase was combined  
with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an  
emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction  
solution (100 mL) and stirred for 10 minutes. A secondary extraction solution  
30 consisting of 2% isopropanol (200 mL) was added and stirred for an additional four  
hours. Hardened microparticles were collected by filtration, washed with water, air  
dried and stored at 4°C. This provided formulation BJ (157 mg, 78.5% yield) with a  
median particle size 54.0 µm. The core load (9.4%), encapsulation efficiency  
(47.0%) and *in vitro* burst (5.31%) were determined by RP-HPLC assay.

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Formulation BK (Leuprolide) – Organic ion assisted method

A microparticle formulation was prepared by an oil-in-water emulsion/solvent extraction method. PLGA polymer (MW 24,000, 160 mg) was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (1000 µL). Leuprolide acetate (40 mg) was dissolved in BnOH (1000 µL) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 50 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (100 mL) and stirred for 10 minutes. A secondary extraction solution consisting of 2% isopropanol (200 mL) was added and stirred for an additional four hours. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BK (120 mg, 60.0% yield) with a median particle size 43.1 µm. The core load (10.6%), encapsulation efficiency (53.0%) and *in vitro* burst (21.1%) were determined by RP-HPLC assay.

Formulation BL (Oxytocin) – Conventional encapsulation method

PLGA polymer (MW 13,000, 180 mg) was dissolved in EtOAc (900 µL). Oxytocin acetate (20 mg) was dissolved in MeOH (100 µL) and added to the polymer solution yielding a milky suspension as the organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 5% EtOAc to provide an emulsion. The emulsion was collected directly into a 10 mM sodium phosphate (pH 8, 0°C, 150 mL) solvent extraction solution and stirred for four hours while warming to room temperature to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BL (143 mg, 71.5% yield) with a median particle size 44.0 µm. The core load (1.67%), encapsulation efficiency (16.7%) and *in vitro* burst (46.3%) were determined by RP-HPLC assay.

Formulation BM (Oxytocin) – Organic ion assisted encapsulation method

PLGA polymer (MW 24,000, 180 mg) was dissolved in EtOAc (1800 µL). Oxytocin acetate (40 mg) was dissolved in MeOH (200 µL) and added to the polymer solution yielding a milky suspension as the organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (150 mL) and stirred for four hours to extract EtOAc. Hardened

microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BM (158 mg, 79.0% yield) with a median particle size 144 µm. The core load (8.9%), encapsulation efficiency (44.5%) and *in vitro* burst (21.1%) were determined by RP-HPLC assay. Table 9 shows that the core load and encapsulation efficiency of two different peptides were increased by the presence of an organic ion.

**Table 9.** Peptide-pamoate complex microparticles by an *in situ* process.

Formulation	Peptide	Pamoate conc.	Core load	Encap. Eff.
BI	leuprolide	0 mM	2.0%	10.0%
BJ	leuprolide	10 mM	9.4%	47.0%
BK	leuprolide	50 mM	10.6%	53.0%
BL	oxytocin	0 mM	1.7%	16.7%
BM	oxytocin	10 mM	8.9%	49.1%

#### Example 5

##### Insulin Encapsulation in PLGA Microparticles Using Organic Acid Salts in the Aqueous Emulsion Phase.

Sodium Dodecylsulfate Microparticle formulations were prepared using an oil-in-water emulsion/solvent extraction method. The organic phase consisted of PLGA polymer (MW 11,800, 150 mg) and PEGylated-insulin (50 mg) dissolved in CH<sub>2</sub>Cl<sub>2</sub> (2 mL). The aqueous phase consisted of 1% PVA and 14 mM SDS. The homogeneous organic and aqueous phases were combined in a ratio of 1:5 to produce an organic in aqueous phase emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (100 mL) and stirred for 10 minutes before adding 100 mL 2% IPA. The solvent extraction solution was then stirred for an additional 3 hours to extract CH<sub>2</sub>Cl<sub>2</sub>. Hardened microparticles were collected by filtration, washed with water, air dried and stored at -20°C. The resulting microparticle had a core load of 21% (encapsulation efficiency 84%). These microparticles were characterized by a large *in vitro* burst of 50% at 24 h in PBS at 37°C.

Disodium Pamoate Microparticle formulations were prepared using an oil-in-water emulsion/solvent extraction method. The organic phase consisted of

PLGA polymer (MW 11,800, 75 mg) and PEGylated-insulin (25 mg) dissolved in  $\text{CH}_2\text{Cl}_2$  (1 mL). The aqueous phase consisted of 1% PVA and 10 mM disodium pamoate. The homogeneous organic and aqueous phases were combined in a ratio of 1:5 to produce an organic in aqueous phase emulsion. The emulsion was  
5 collected directly into a 0.3% PVA solvent extraction solution (50 mL) and stirred for 10 minutes before adding water (100 mL). The solvent extraction solution was then stirred for an additional 3 hours to extract  $\text{CH}_2\text{Cl}_2$ . Hardened microparticles were collected by filtration, washed with water, air dried and stored at  $-20^\circ\text{C}$ . The resulting microparticles had a core load of 18% (encapsulation efficiency 78%) and a final  
10 PEGylated-insulin/pamoate ratio of 1:2. In contrast to the microparticles made with SDS, these microparticles had a low *in vitro* burst of 5% in PBS at  $37^\circ\text{C}$ .

### Example 6

#### 15 Evaluation of the Pharmacokinetics of Octreotide in PLGA Microparticles after Administration to Sprague Dawley Rats.

Blood serum levels were measured for octreotide released from PLGA microparticle formulations injected subcutaneously in rats. Animals ( $n=6/\text{group}$ ) were treated once by subcutaneous injection of a single dose level ( $\sim 8\text{-}10\text{ mg/kg}$ ) of six different octreotide PLGA microparticle formulations. At hours 1 and 6, and on days  
20 1, 4, 7, 11, 14, 20, 28, 42 and 54, serum samples were obtained from each animal to evaluate the octreotide pharmacokinetics. Serum concentrations were measured by a commercially available extraction-free radioimmunoassay kit (#S-2211) (Peninsula Labs). The Limit of Quantitation (LOQ) of the assay was 0.1 ng/mL. The mean octreotide serum concentrations for each time point are reported in Table 10. The  
25 preparation of the octreotide PLGA formulations tested is described below.

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**Table 10.** Mean octreotide serum levels (ng/mL) after a single subcutaneous treatment in rats.

Formulation	Dose (mg/Kg)	Sample Day					
		0	0.04	0.25	1	4	7
BC	10.2	0.00	39.75	3.83	0.62	1.44	3.07
BD	8.9	0.00	39.95	4.00	0.95	1.66	3.41
BE	9.7	0.00	36.35	4.09	2.04	2.13	2.59
BF	8.6	0.00	39.75	3.89	1.33	2.54	3.06
BG	9.2	0.00	29.70	3.82	2.06	1.85	2.28
BH	9.4	0.00	39.80	4.13	2.90	3.70	3.64
		11	14	20	28	42	54
BC	3.71	3.42	3.51	1.95	0.39	0.00	
BD	3.64	3.44	2.03	1.04	0.45	0.00	
BE	2.89	2.94	2.19	1.81	3.09	0.90	
BF	3.16	2.89	1.43	0.64	1.52	0.00	
BG	1.96	2.00	1.70	0.97	2.24	1.39	
BH	3.54	3.44	2.34	1.70	1.63	0.05	

**Preparation and characterization of octreotide formulations used in the animal study.**

**Formulation BC**

PLGA polymer (MW 24,000, 720 mg) was dissolved in EtOAc (4000  $\mu$ L). Octreotide acetate (80 mg) was dissolved in BnOH (4000  $\mu$ L) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (600 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BC (754 mg, 94% yield) with a median particle size 55.0  $\mu$ m. The core load (8.5%), encapsulation efficiency (85.0%) and *in vitro* burst (7.4%) were determined by RP-HPLC assay.

## Formulation BD

PLGA polymer (MW 24,000, 680 mg) was dissolved in EtOAc (4000  $\mu$ L). Octreotide acetate (120 mg) was dissolved in BnOH (4000  $\mu$ L) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (600 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BD (694 mg, 94% yield) with a median particle size 58.7  $\mu$ m. The core load (11.8%), encapsulation efficiency (78.7%) and *in vitro* burst (4.1%) were determined by RP-HPLC assay.

## Formulation BE

PLGA polymer (MW 24,000, 680 mg) was dissolved in EtOAc (4000  $\mu$ L). Octreotide acetate (120 mg) was dissolved in BnOH (4000  $\mu$ L) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (600 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BE (727 mg, 91% yield) with a median particle size 52.2  $\mu$ m. The core load (11.6%), encapsulation efficiency (77.3%) and *in vitro* burst (2.75%) were determined by RP-HPLC assay.

## Formulation BF

PLGA polymer (MW 24,000, 640 mg) was dissolved in EtOAc (4000  $\mu$ L). Octreotide acetate (160 mg) was dissolved in BnOH (4000  $\mu$ L) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (600 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BF (766 mg, 95.8% yield) with a median particle size



47.7  $\mu\text{m}$ . The core load (14.7%), encapsulation efficiency (73.5%) and *in vitro* burst (5.5%) were determined by RP-HPLC assay.

#### Formulation BG

5 PLGA polymer (MW 28,000, 640 mg) was dissolved in EtOAc (4000  $\mu\text{L}$ ). Octreotide acetate (160 mg) was dissolved in BnOH (4000  $\mu\text{L}$ ) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent  
10 extraction solution (600 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BG (715 mg, 89.3% yield) with a median particle size 48.7 $\mu\text{m}$ . The core load (11.9%), encapsulation efficiency (59.5%) and *in vitro* burst (2.3%) were determined by RP-HPLC assay.

15

#### Formulation BH

PLGA polymer (MW 14,000, 560 mg) was dissolved in EtOAc (4000  $\mu\text{L}$ ). Octreotide acetate (240 mg) was dissolved in BnOH (4000  $\mu\text{L}$ ) and added to the polymer solution yielding a homogeneous organic phase. The resulting organic  
20 phase was combined with a 1% PVA aqueous phase containing 10 mM disodium pamoate to provide an emulsion. The emulsion was collected directly into a 0.3% PVA solvent extraction solution (600 mL) and stirred for four hours to extract EtOAc. Hardened microparticles were collected by filtration, washed with water, air dried and stored at 4°C. This provided formulation BH (680 mg, 85.0% yield) with a median  
25 particle size 40.6  $\mu\text{m}$ . The core load (17.4%), encapsulation efficiency (58.0%) and *in vitro* burst (6.8%) were determined by RP-HPLC assay.

In all cases, release of the bioactive agent *in vivo* occurred for at least 42 days and in some cases for as many as 54 days.

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All of the compositions and methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of particular embodiments, it will be apparent to those of skill in the art that variations  
35 may be applied to the compositions, and methods and in the steps or in the

sequence of steps of the methods described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents that are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope, and concept of the invention as defined by the appended claims.